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HELICOPTER NOISE CONTOUR DEVELOPMENT TECHNIQUES AND DIRECTIVITY--ETC(U)
SEP 80 J S NEWMAN

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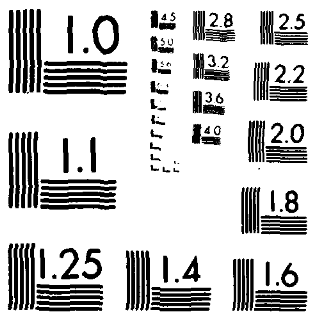

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US Department of Transportation
Federal Aviation Administration

(6) # Helicopter Noise Contour Development Techniques and Directivity Analysis.

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By J. Steven Newman

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16. Abstract

This paper briefly summarizes techniques which have been developed for use in creating helicopter air-to-ground, noise-distance relationships. Discussion is provided concerning FAA efforts to establish an accurate and practical method (which considers source directivity) for modeling the noise impact associated with helicopter operations. Plots of normalized directivity effects are provided for eight helicopters in various modes of flight.

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1.0 INTRODUCTION

This paper briefly summarizes techniques which have been developed for use in creating helicopter air-to-ground, noise-distance relationships. Discussion is provided concerning FAA efforts to establish an accurate and practical method (which considers source directivity) for modeling the noise impact associated with helicopter operations. Plots of normalized directivity vectors are provided for eight helicopters in various modes of flight.

2.0 REVIEW OF METHODOLOGIES FOR DEVELOPING HELICOPTER AIR-TO-GROUND, NOISE/DISTANCE CURVES FOR USE IN GENERATING NOISE CONTOURS

The following paragraphs describe methodologies for developing air-to-ground noise/distance curves for use in generating helicopter noise contours using measured data along with SAE-ARP-866A atmospheric absorption attenuation coefficients, the spherical spreading law, and various assumptions concerning the effect of distance on the flyover 10-dB down time history.

2.1 Method 1 - U.S. Air Force

Jerry Speakman[1] of the U.S. Air Force Wright Patterson Aero-Medical Center has developed a set of air-to-ground noise exposure versus distance curves based on FAA noise data reported in 1977 by True and Rickley and adjusted to agree with FAA data reported in 1979 by Newman and Rickley. The USAF methodology begins with the acoustical spectra

from the time at which the maximum perceived noise level (PNLM) occured. This spectrum is extrapolated to distances using the spherical spreading law and atmospheric absorption corrections provided in SAE-ARP-866A. This spectrum is used along with a 6 dB per decade factor (to account for the change in event duration) to arrive at a value of Noise Exposure Level (NEL), or Effective Perceived Noise Level (EPNL).

2.2 Method 2 - U.S. Army

Paul Schomer[2] of the U.S. Army Construction Engineering Research Laboratory (CERL) has developed a procedure using data measured by CERL at Ft. Rucker during 1974. The CERL method starts with the spectra for each one-half second sample of the entire flyover time history (noise floor limited). Each spectrum is extrapolated to distances using the spherical spreading law, along with ARP-866A. The decayed time history is then used to compute EPNL (or NEL) at distance. Use of this methodology is appropriate out to slant distances of approximately 3,000 feet. The recorded time history is not long enough to project beyond 3,000 feet. CERL data (unpublished) have shown a net 7 dB/decade attenuation between 0 and 1,000' slant ranges, and 10 dB/decade attenuation between 1,000' and 5,000' slant ranges.

2.3 Method 3 - FAA, Level Flyovers 300 Feet to 2,500 Feet

In the June 1980 FAA noise measurement program, level flyovers were conducted at constant speeds for the following altitudes: 300', 500', 700', 1,000', 1,500', 2,000', and 2,500'. Data were recorded for nine

microphone locations and also measured using a precision integrating sound level meter (PISLM) at a single location. The PISLM data have been plotted versus test target altitude and provided in a preliminary report,[3] FAA-AEE-80-34. These data (not corrected to standard T, R.H.), can be used to develop helicopter noise contours for slant distances between 300' and 2,500'. Extrapolation of these data can also be accomplished for longer slant distances.

3.0 DISCUSSION OF TECHNIQUES UNDER DEVELOPMENT BY THE FAA

The June 1978 FAA helicopter noise measurement program provided data reported in FAA-AEE-79-3,[4] prepared by E. J. Rickley of the DOT, Transportation Systems Center (TSC) Noise Measurement and Assessment Laboratory in concert with this author. While FAA-AEE-79-3 was principally concerned with noise certification aspects of the measured data, a follow-on or Phase II report (also an FAA-TSC collaboration) is in preparation which will specifically address helicopter noise contours, source directivity, sound level time histories, and frequency spectra.

The processing of data included considerations for developing Noise Exposure Level (NEF) and Day-Night Sound Level (Ldn) noise contours as well as Time Above (TA) contours. The TA requirements mandated that sound level data versus distance and directivity angle be generated. These level/distance/directivity data have been developed for two directivity angles: (1) the elevation angle formed between the slant range ray (SR) and the ground surface, and (2) the angle between the SR and the helicopter flight path. Data have been generated for takeoffs, approaches, and level flyovers for centerline as well as sideline sites.

The "as measured" spectrum for the helicopter position for each 10 degree increment in elevation angle (from the centerline center microphone location) was adjusted to standard day temperature and relative humidity (77°F, 70 percent) absorption conditions. The spectrum was indexed by the two angles identified above and the slant distance (spherical coordinates). The sound pressure level (SPL) values were then adjusted to distances between 200 feet and 20,000 feet (holding the angles constant) in accordance with the spherical spreading law and consideration of absorption along the extended path. No adjustment was made for excess ground attenuation.

The generated data files provide the means to create a three-dimensional directivity/distance/level model for use in TA and noise contour development. The development of NEL values for (each) location on the ground will require construction of a dB(A) time history using the multi-angle/distance indexed dB(A) values associated with increments along the helicopter flight path. This procedure would also require development of an interpolation routine to assign values to angle-pairs not stored in the data file.

In restrospect, this methodology (clearly more comprehensive than others) has immense computational requirements which restrict its usefulness. While unrealistic as an operational component of a noise contour generating computer model such as the FAA Integrated Noise Model (INM), it may be feasible to construct a separate model for use in computing noise exposure for a limited number of grid locations. This

model can be used to compute NEL for various angle-pairs. In turn, a curve or algorithm could be fit to these data providing NEL as a function of CPA distance and CPA elevation angle (for sideline locations).

A plan under consideration might use the complex data files described above to develop NEL versus distance information for the centerline-center microphone location as the fundamental contour generating data base. Using dB(A) sideline directivity information similar to that presented in the next section it may be possible to generate a CPA-elevation angle correction (for sideline locations) to the centerline-center NEL-distance data.

4.0 HELICOPTER NOISE DIRECTIVITY ANALYSES

The plots shown in this section are samples of helicopter directivity characteristics generated as part of the Phase II reduction of data acquired in the 1978 FAA Helicopter Noise Measurement Program.[5] The diagrams provide the two-dimensional directivity within the vertical plane coincident with the helicopter ground track. A sound level reference semi-circle corresponding to the lowest dB(A) directivity value is provided on each plot. The vector lengths outside the semi-circle correspond linearly to change in level, where 1 cm = 1 dB. A scale is provided to assure proper interpretation in the event length distortion occurs in reproducing the plots.

The angles in each plot increase clockwise from the helicopter flight path extension ahead of the helicopter. The first vector angle is identified in each case and subsequent vectors represent approximately

10 degree incremental increases in angle. The vector lengths represent the sound level normalized to a distance of 500 feet. This is hereafter referred to as the normalized directivity (ND). For an observer on the ground, the "lower angle" vectors (near 30^o or near 150^o) will effectively shrink due to increased path length. Assuming only spherical spreading (additional absorption being small), the 30^o and 150^o vectors would diminish by 6 dB or 6 cm. Other vector length adjustments for a ground observer during level flyover include:

Angle	Level Adjustment for Ground Observer
30 or 150	6 dB
40 or 140	3.8 dB
50 or 150	2.3 dB
60 or 120	1.2 dB
70 or 110	.5 dB
80 or 110	.1 dB
90	0 dB

The vector length adjustments for takeoff and approach would be very close to those shown above.

The directivity envelope seen by a ground observer (GO) is shown on each plot. These diagrams dramatically show the dominance of different helicopter noise sources at different angles as well as their relative intensity levels. For example, the pronounced frontal lobe exhibited by the SA-330J (Puma) possibly suggests that the strong forward radiated compressor whine dominates the resulting NEL value. On the other hand, the SA-341G (Gazelle) exhibits a comparatively weak forward radiation component but a dominate tail rotor influence. The Sikorsky [illegible] is seen to be nearly an omnidirectional source dominated by main

rotor influences. The following sections give a very brief qualitative assessment of observed directivity characteristics. At this point, no attempt will be made to mathematically model the directivity patterns as monopoles or dipoles or combinations of these or other functions. The matter of identifying the noise generating mechanism associated with various directivity lobes also remains to be addressed. The abbreviations used below include:

ND: Normalized Directivity (to a distance of 500 feet)

GO: Ground Observer Directivity

CPA: Closest Point of Approach

4.1 Bell 212

The directivity characteristics exhibited by the Bell 212 are discussed below:

Takeoff (Figure 4.1.1)

- ND Pattern: Leading, moderate width
- ND MAX: Near 60 degrees
- GO Pattern: Leading, moderate width
- GO MAX: Near 70 degrees

Approach (Figure 4.1.2)

- ND Pattern: Moderate-narrow width leading
- ND MAX: Near 30 degrees
- GO Pattern: Very narrow width, highly directive, leading
- GO MAX: Near 60 degrees

Level Flyover (Figure 4.1.3)

- ND Pattern: Moderate width, leading
- ND MAX: Near 30 degrees
- GO Pattern: Moderate-narrow lobe, leading
- GO MAX: Near 60 degrees

4.2 SA-330J (Puma)

Takeoff (Figure 4.2.1)

- ND Pattern: Approximately omnidirectional
- ND MAX: Near 50 degrees
- GO Pattern: Wide lobe
- GO MAX: Near CPA (90 degrees)

Approach (Figure 4.2.2)

- ND Pattern: Highly directive, ahead of SA-330J
- ND MAX: Near 30 degrees
- GO Pattern: wide, leading, rapidly diminishing after CPA
- GO MAX: Near 30 degrees

Level Flyover (Figure 4.2.3)

- ND Pattern: Ahead of helicopter, moderate width
- ND MAX: Near 40 degrees
- GO Pattern: Also leading
- GO MAX: 50 degrees

4.3 S-61

Takeoff (Figure 4.3.1)

- ND Pattern: Approximately omnidirectional
- ND MAX: Approximately 70 degrees
- GO Pattern: Very wide
- GO MAX: Close to CPA

Approach (Figure 4.3.2)

- ND Pattern: Wide leading
- ND MAX: Approximately 80 degrees
- GO Pattern: Narrow
- GO MAX: Near CPA

Takeoff (Figure 4.3.3)

- ND Pattern: Very wide teardrop
- ND MAX: Near 70 degrees
- GO Pattern: Wide teardrop
- GO MAX: Near CPA

4.4 BO-105

Takeoff (Figure 4.4.1)

- ND Pattern: Sharp forward lobe
- ND MAX: near 40 degrees
- GO Pattern: Narrow leading lobe
- GO MAX: Near 50 degrees

Approach (Figure 4.4.2)

- ND Pattern: Broad irregular leading
- ND MAX: Near 30 degrees
- GO Pattern: Broad irregular leading
- GO MAX: Near 50 degrees

Level Flyover (Figure 4.4.3)

- ND Pattern: Moderate leading
- ND MAX: Near 50 degrees
- GO Pattern: Narrow-moderate leading lobe
- GO MAX: Near 60 degrees

4.5 CH-53

Takeoff (Figure 4.5.1)

- ND Pattern: Very irregular broad leading
- ND MAX: Near CPA
- GO Pattern: Irregular broad leading
- GO MAX: Near CPA

Approach (Figure 4.5.2)

- ND Pattern: Sharp leading lobe at 30 degrees
  medium width lobe at CPA
  generally irregular
- ND MAX: Near 30 degrees
- GO Pattern: Narrow lobe centered on CPA
- GO MAX: Near CPA

Level Flyover (Figure 4.5.3)

- ND Pattern: Strong broad forward lobe
- ND MAX: Near 40 degrees
- GO Pattern: Broad irregular lobe leading
- GO MAX: Near 70 degrees

4.6 SA-341G

Takeoff (Figure 4.6.1)

- ND Pattern: Very irregular, strong rear lobe
- ND MAX: Near 140 degrees
- GO Pattern: Very irregular, strong rear lobe
- GO MAX: Near 120 degrees

Approach (Figure 4.6.2)

- ND Pattern: Generally omnidirectional with rear quadrant emphasis
- ND MAX: Near 110 degrees
- GO Pattern: Sharp rear lobe
- GO MAX: Near 110 degrees

Level Flyover (Figure 4.6.3)

- ND Pattern: Strong rear lobe
- ND MAX: Near 140 degrees
- GO Pattern: Broad lobe near CPA
- GO MAX: Near CPA

4.7 Bell 206L

Takeoff (Figure 4.7.1)

- ND Pattern: Strong (narrow) trailing lobe, moderate to leading lobe
- ND MAX: Near 150 degrees
- GO Pattern: Narrow lobe near CPA
- GO MAX: Near CPA

Approach (Figure 4.7.2)

- ND Pattern: Broad leading lobe, narrow pronounced trailing lobe
- ND MAX: Near 70 degrees
- GO Pattern: Sharply pointed, moderate lobe
- GO MAX: Near 70 degrees

Level Flyover (Figure 4.7.3)

- ND Pattern: Strong leading
- ND MAX: Near 30 degrees
- GO Pattern: Broad, slightly leading
- GO MAX: Near 80 degrees

4.8 Hughes 500C

Takeoff (Figure 4.8.1)

- ND Pattern: Very strong, broad lobe, slightly trailing
- ND MAX: Near 110 degrees
- GO Pattern: Broad lobe centered near CPA
- GO MAX: Near 100 degrees

Approach (Figure 4.8.2)

- ND Pattern: Strong, wide trailing
- ND MAX: Near 140 degrees
- GO Pattern: Medium "teardrop" lobe centered near CPA
- GO MAX: Near 100 degrees

Level Flyover (Figure 4.8.3)

- ND Pattern: Pronounced leading and trailing lobes
- ND MAX: Near 120 degrees
- GO Pattern: Narrow lobe near 110 degrees
- GO MAX: Near 110 degrees

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER ______

TEST DATE ______

NUMBER OF EVENTS AVERA ______

METRIC ______

VECTOR LENGTH REPRESENTS ... GROUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 76.1

OPERATION Takeoff

SITE 150 m. East

REFERENCE SLANT RANGE 500 Feet

SCALE : 1cm = 1dB outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS
-ANGLES INCREASE CLOCKWISE.

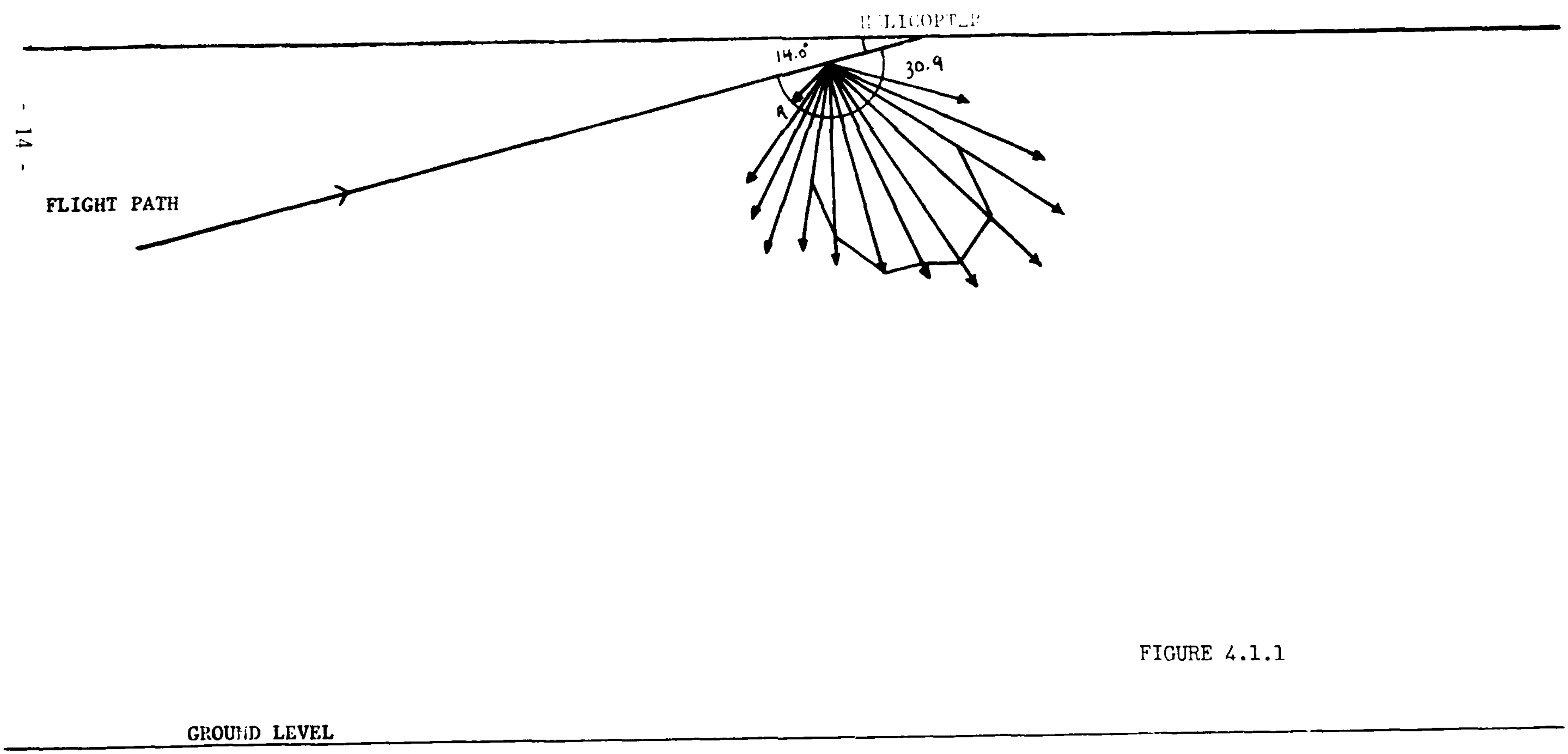


FIGURE 4.1.1

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER Bell 212
TEST DATE 6/15/78
NUMBER OF EVENTS AVERAGED 4
METRIC dB(A)

OPERATION APPROACH
SITE 150 m. East
REFERENCE SLANT RANGE 500 Feet

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 78.8

SCALE : 1cm = 1dB outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

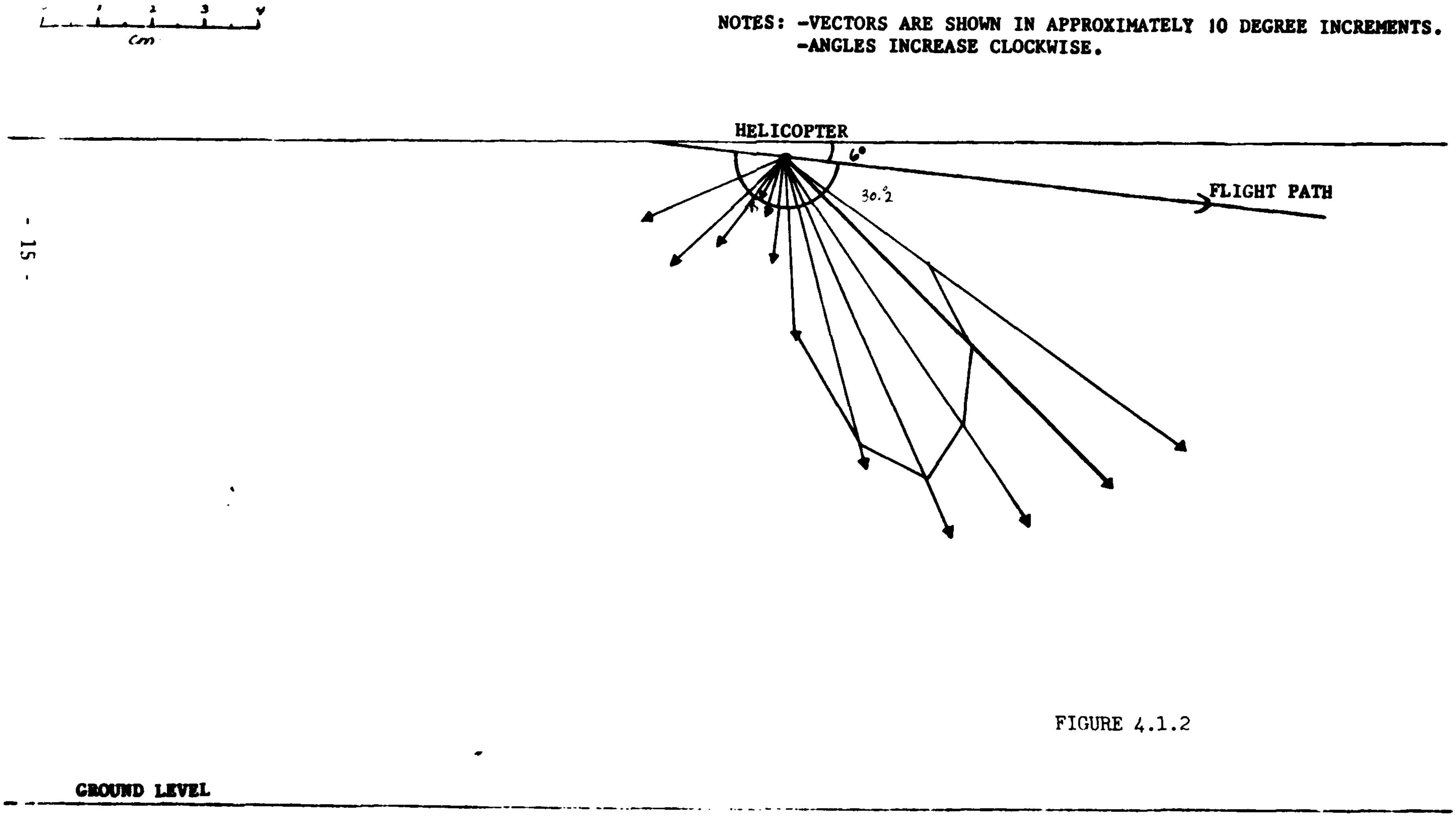


FIGURE 4.1.2

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER ______ | OPERATION Level Flyover
TEST DATE ______ | SITE 150 m. East
NUMBER OF EVENTS AVERAGED ______ | REFERENCE SLANT RANGE 500 Feet
METRIC ______

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 76.7

SCALE : 1cm = 1dB outside reference semicircle

0 1 2 3 4
cm

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMEN
-ANGLES INCREASE CLOCKWISE.

FLIGHT PATH

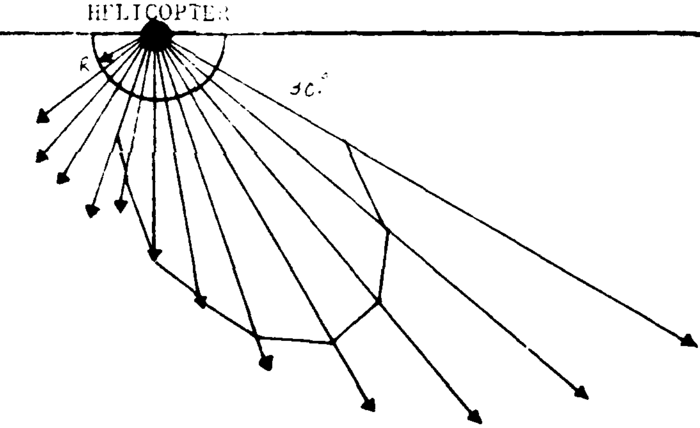


FIGURE 4.1.3

GROUND LEVEL

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER Puma SA-330

TEST DATE 6/12/78

NUMBER OF EVENTS AVERAGED 4

METRIC dB(A)

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 77.1

OPERATION Takeoff

SITE 150 m. East

REFERENCE SLANT RANGE 500 Feet

SCALE : 1cm = 1dB outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

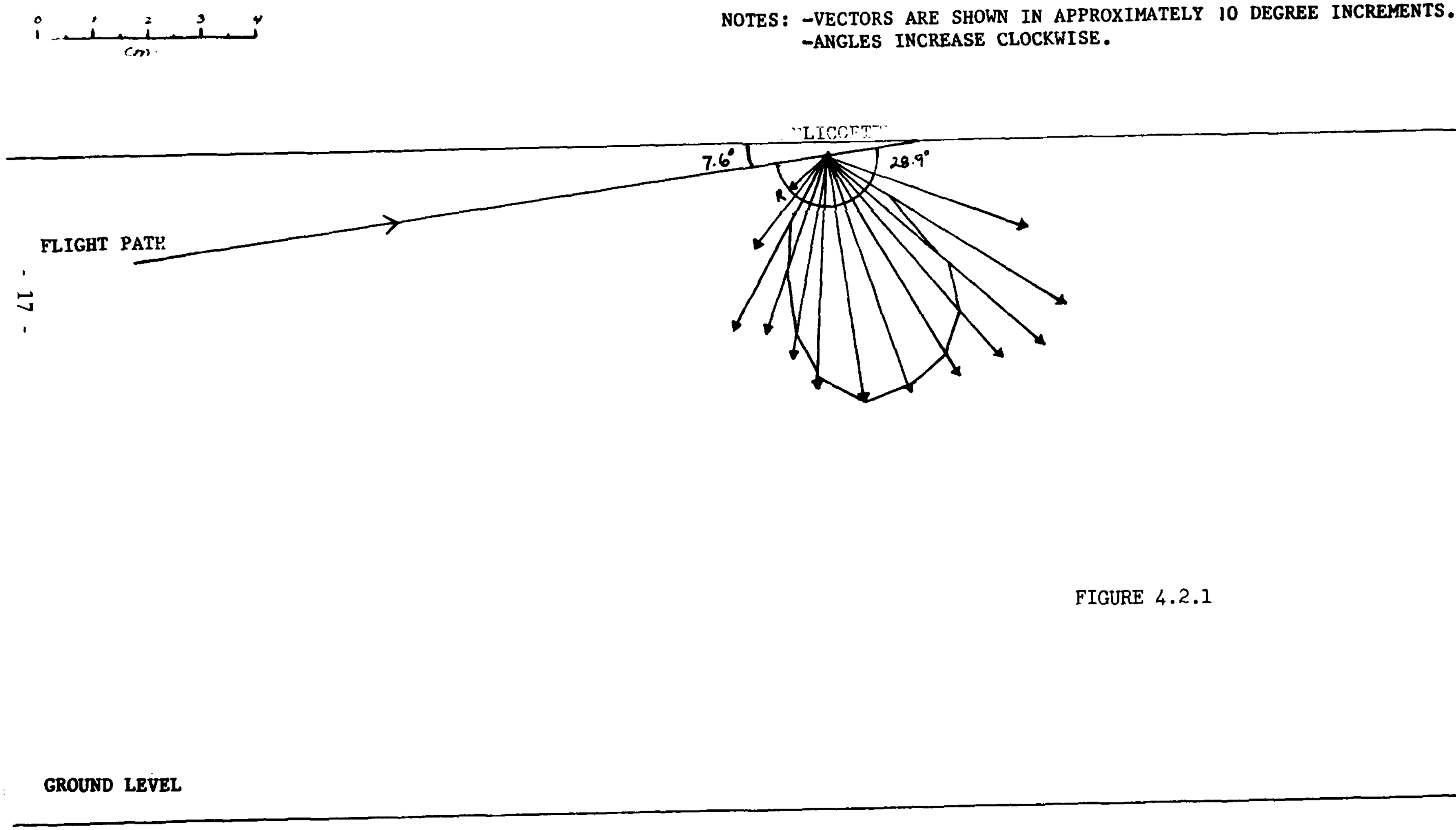


FIGURE 4.2.1

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER ______ OPERATION APPROACH

TEST DATE ______ SITE 150 m East

NUMBER OF EVENTS AVERAGED ______ REFERENCE SLANT RANGE 500 Feet

METRIC dB(A)

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 73.7

SCALE : 1cm = 1dB outside reference semicircle

0 1 2 3 4 cm

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

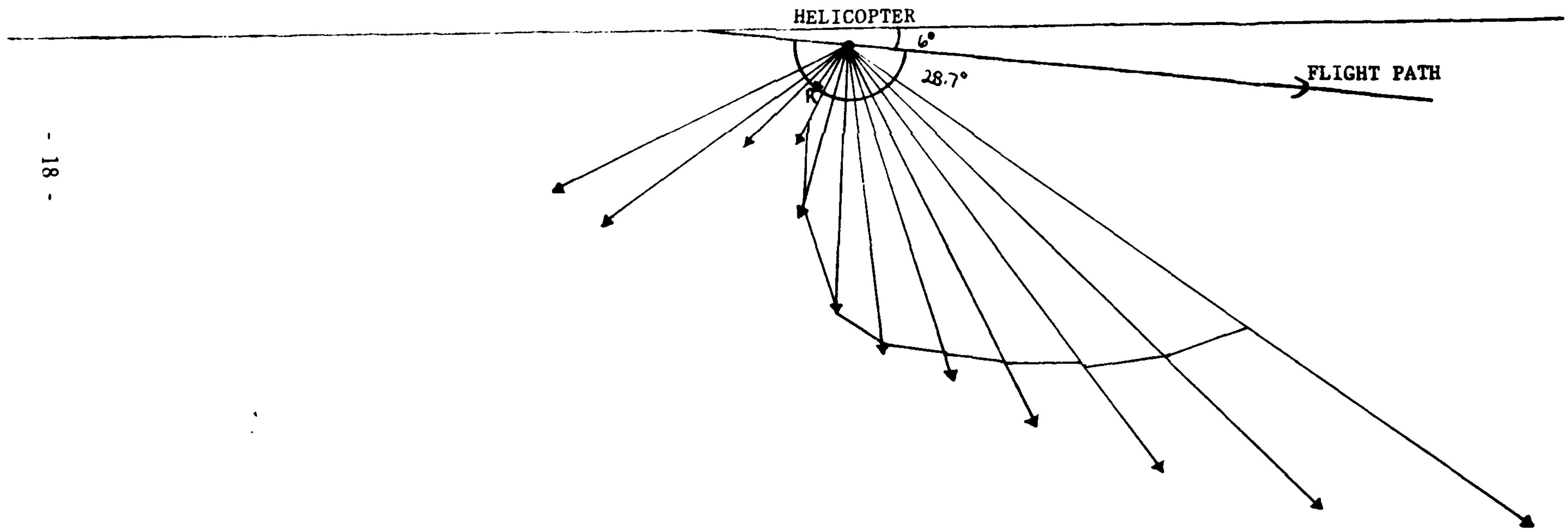


FIGURE 4.2.2

GROUND LEVEL

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER Puma SA 330

TEST DATE 6/12/78

NUMBER OF EVENTS AVERAGED 1

METRIC dB(A)

OPERATION Level Flyover

SITE 150 m East

REFERENCE SLANT RANGE 500 Feet

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 77.8

SCALE : 1cm = 1dB outside reference semicircle

0 1 2 3 4

cm.

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

FLIGHT PATH

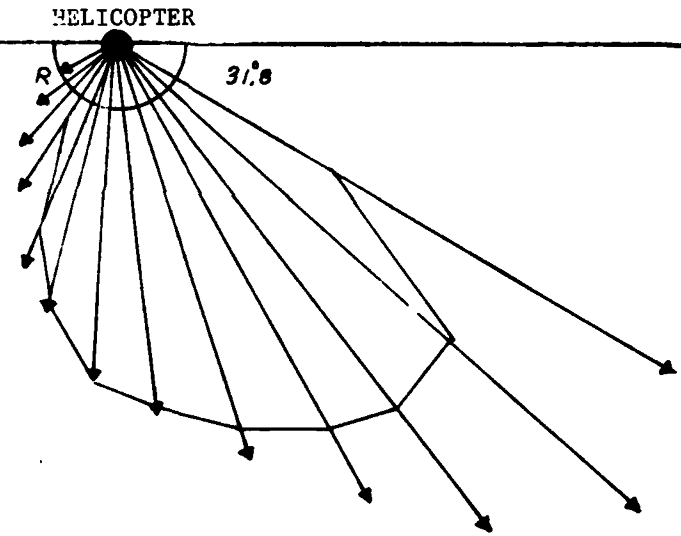


FIGURE 4.2.3

GROUND LEVEL

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER [illegible]

TEST DATE [illegible]

NUMBER OF EVENTS AVERAGED [illegible]

METRIC [illegible]

OPERATION Takeoff

SITE 150 m East

REFERENCE SLANT RANGE 500 Feet

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 79.0

SCALE : 1cm = 1dB outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

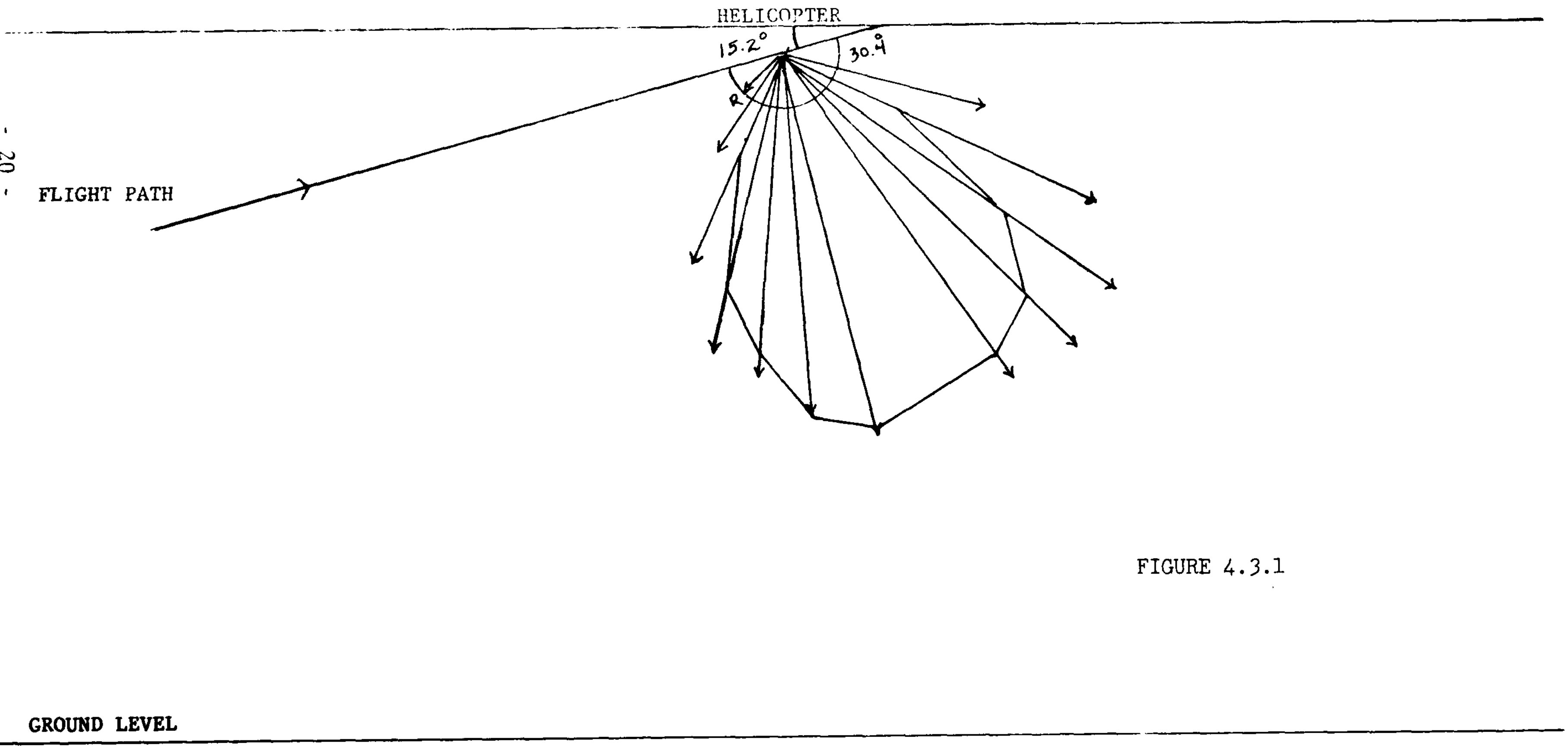


FIGURE 4.3.1

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER
TEST DATE
NUMBER OF EVENTS AVERAGED
METRIC
VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 78.0

OPERATION APPROACH
SITE 150 m East
REFERENCE SLANT RANGE 500 Feet

SCALE : 1cm = 1dB outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

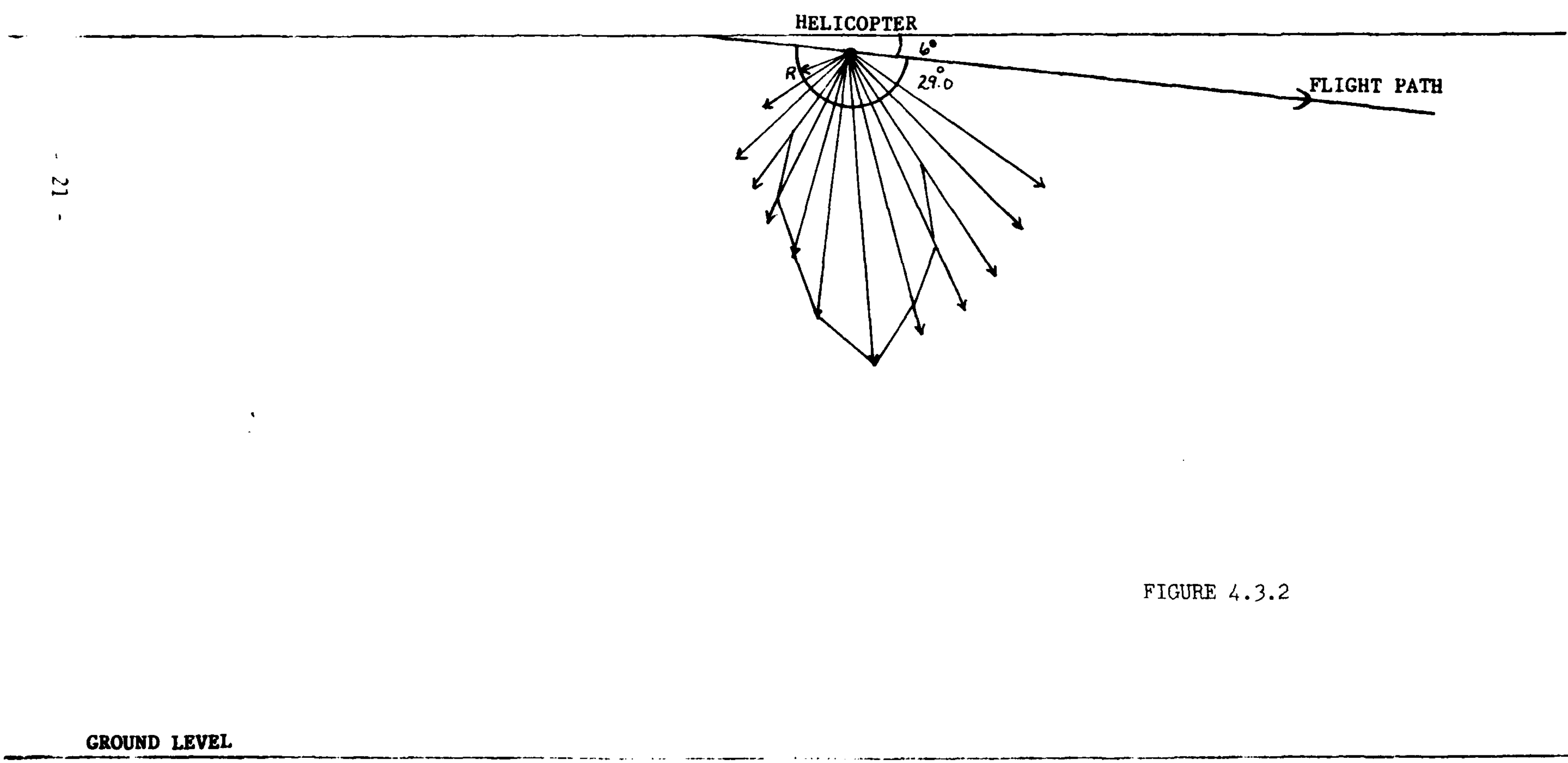


FIGURE 4.3.2

OPERATION Level Flyover

SITE 150 m East

REFERENCE SLANT RANGE 500 Feet

NUMBER OF EVENTS AVE.

METRIC

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 91.4

SCALE : 1cm = 1dB outside reference semicircle

0 1 2 3 4

cm

NOTES: – VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENT
– ANGLES INCREASE CLOCKWISE.

FLIGHT PATH

HELICOPTER

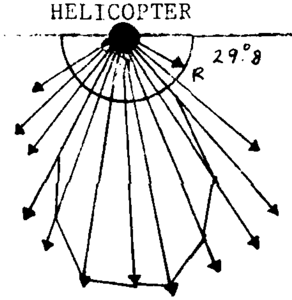


FIGURE 4.3.3

GROUND LEVEL

HELICOPTER DIRECTIVITY ANALYSIS

...OPTER [illegible]

...DATE [illegible]

...MBER OF EVENTS AVERAGED [illegible]

METRIC [illegible]

OPERATION Takeoff

SITE 150 m East

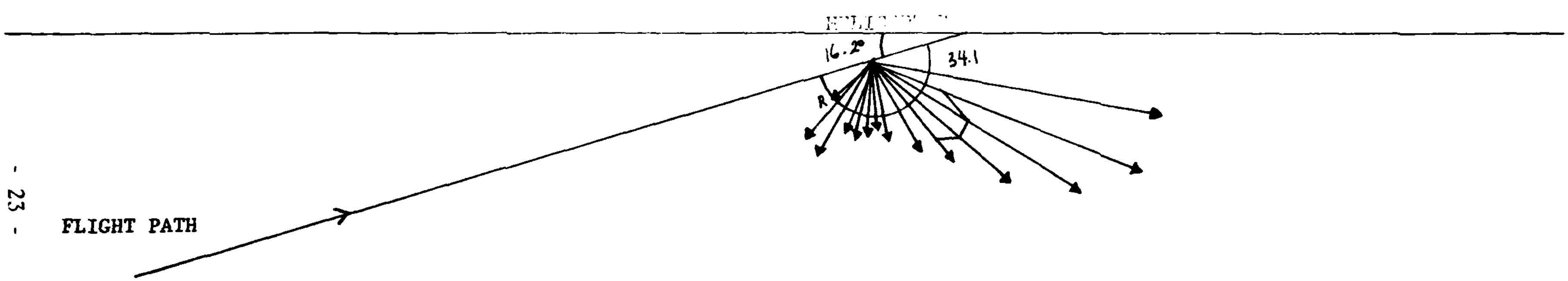
REFERENCE SLANT RANGE 500 Feet

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 73.2

SCALE : 1cm = 1dB *outside reference semicircle*

0 1 2 3 4
cm

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.



GROUND LEVEL

FIGURE 4.4.1

HELICOPTER DIRECTIVITY ANALYSIS

OPERATION APPROACH

SITE 150 m East

REFERENCE SLANT RANGE 500 Feet

[illegible]

[illegible]

NUMBER OF [illegible]

[illegible]

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 73.6

SCALE : 1cm = 1dB outside reference semicircle

0 1 2 3 4

cm

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

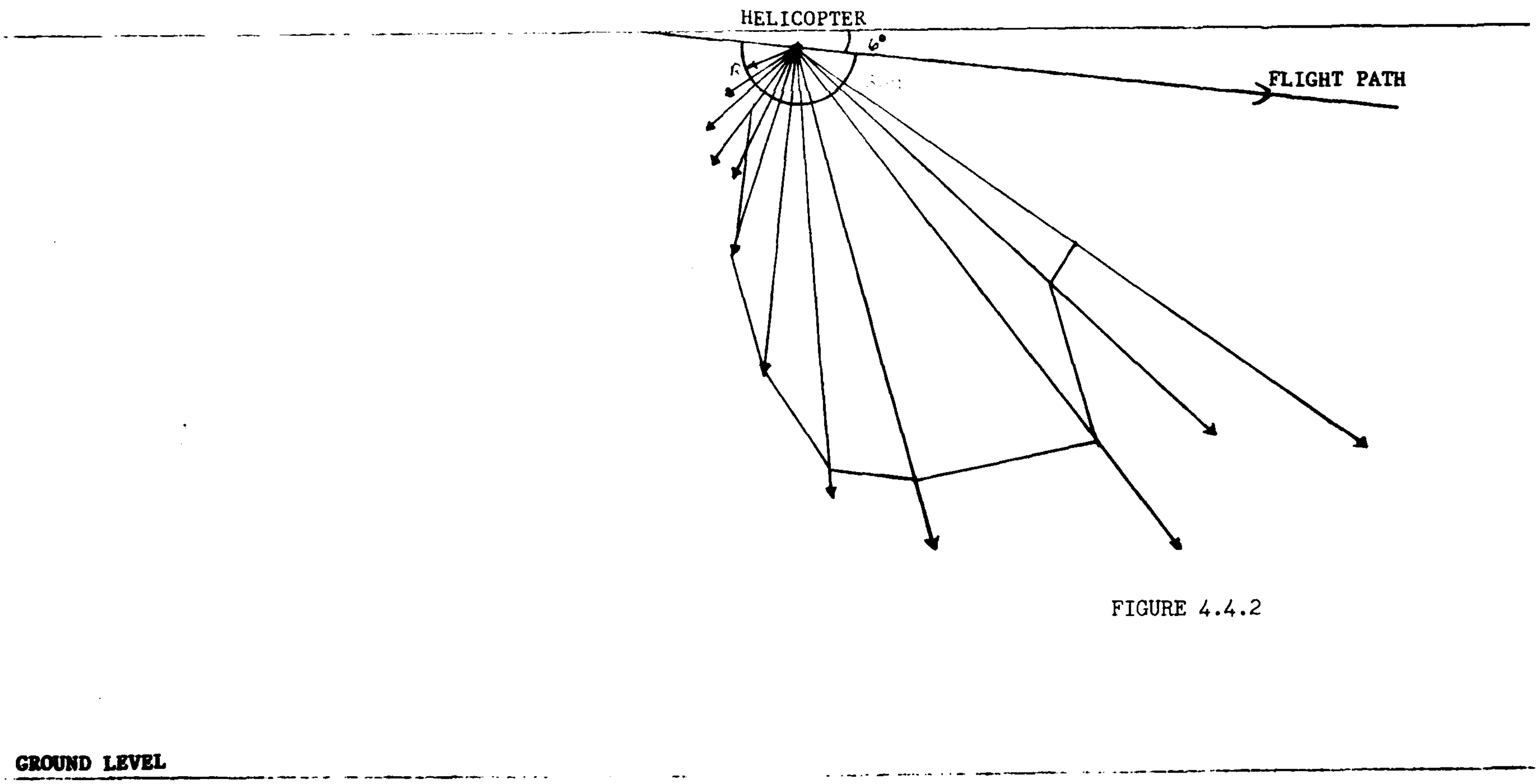


FIGURE 4.4.2

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER Boelkow BO 105

TEST DATE June 12, 1978

NUMBER OF EVENTS AVERAGED 1

METRIC dB(A)

OPERATION Level Flyover

SITE 150 m East

REFERENCE SLANT RANGE 500 Feet

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 75.3

SCALE : 1cm = 1dB outside reference semicircle

0 1 2 3 4
cm.

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE

FLIGHT PATH

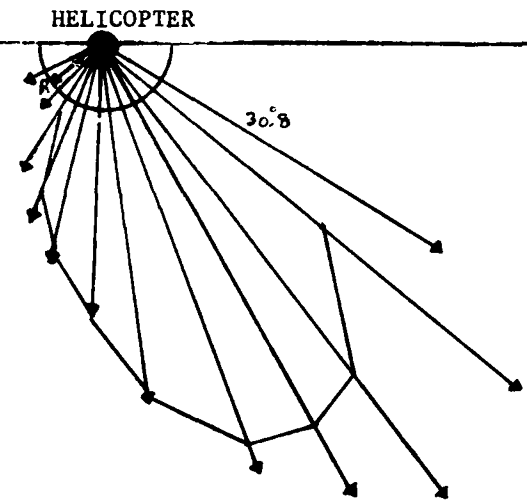


FIGURE 4.4.3

GROUND LEVEL

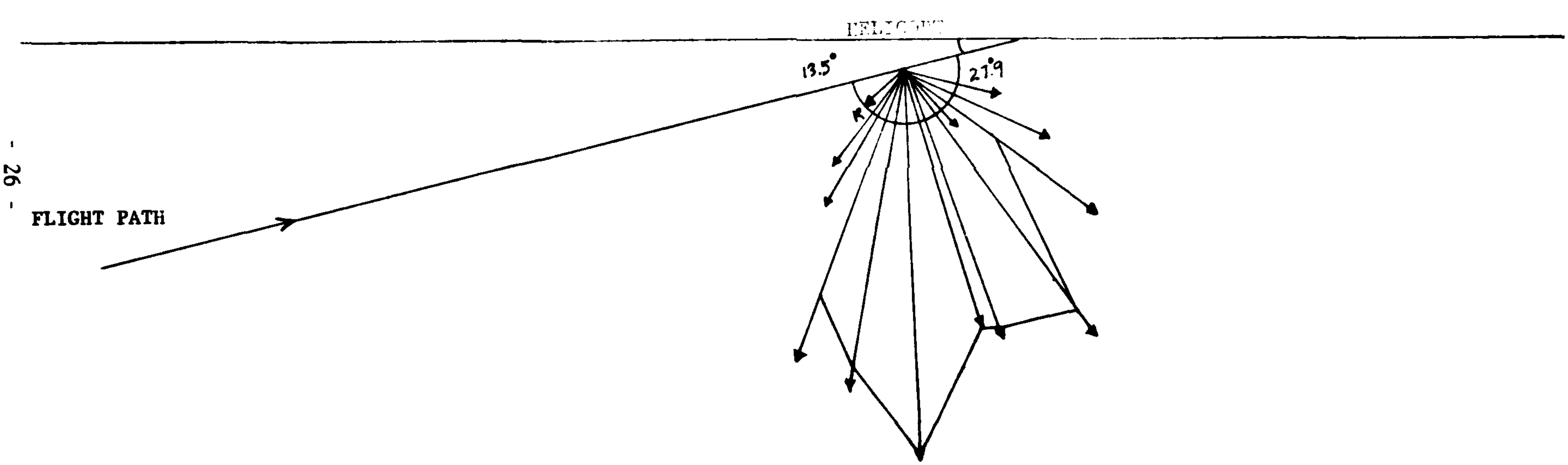
HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER [illegible]	OPERATION Takeoff
TEST DATE [illegible]	SITE 150 m East
NUMBER OF EVENTS AVERAGED ______	REFERENCE SLANT RANGE 500 Feet
METRIC [illegible]	

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 90.5

SCALE : 1cm = 1dB outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.



GROUND LEVEL

FIGURE 4.5.1

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER Sikorsky CH 53

TEST DATE June 15, 1978

NUMBER OF EVENTS AVERAGED 3

METRIC dB(A)

OPERATION APPROACH

SITE 150 m East

REFERENCE SLANT RANGE 500 Feet

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 81.4

SCALE : 1cm = 1dB outside reference semicircle

0 1 2 3 4
cm

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

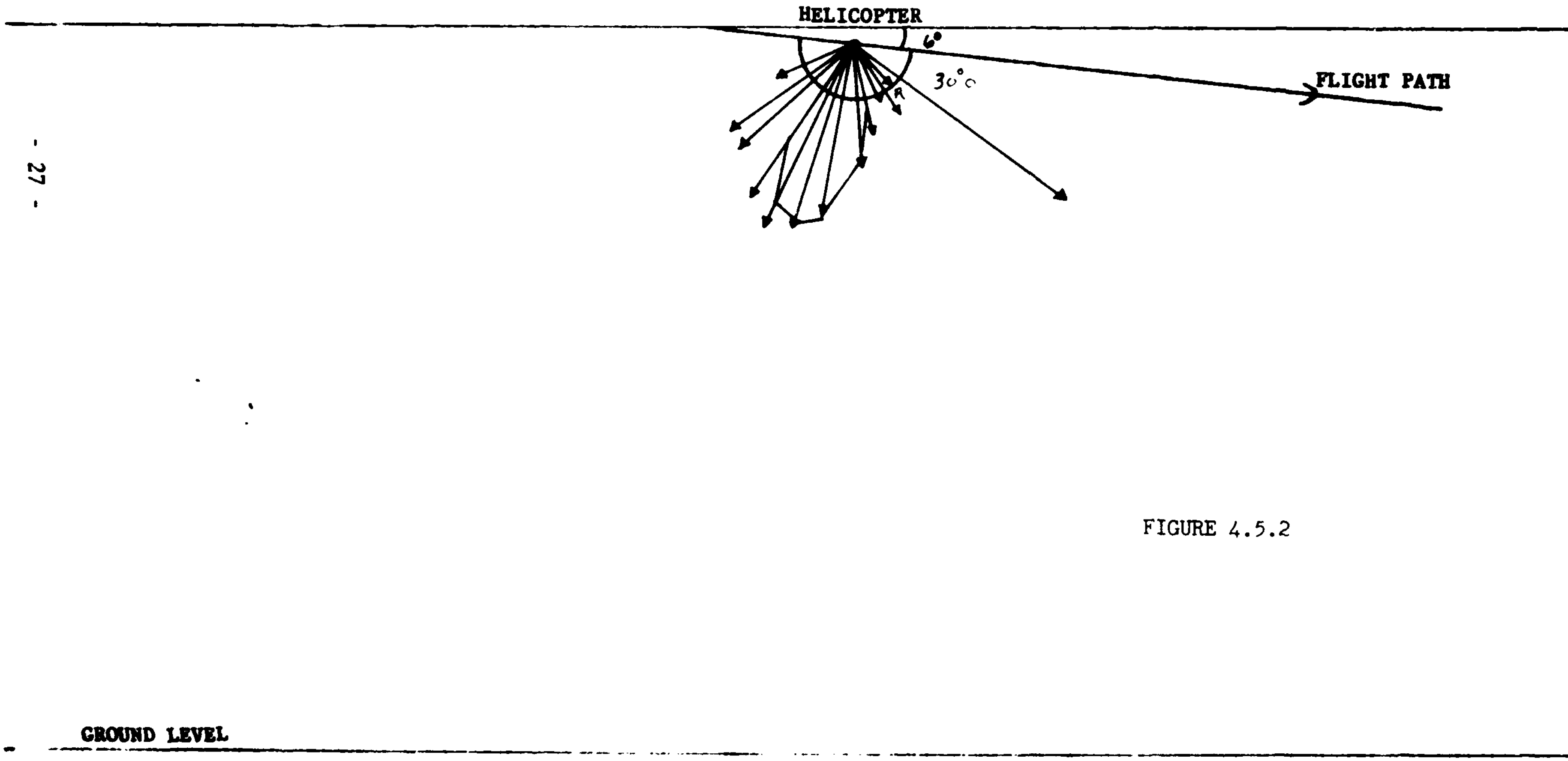


FIGURE 4.5.2

HELICOPTER DIR[illegible] ANALYSIS

HELICOPTER Sikorsky CH-53

TEST DATE June 15

NUMBER OF EVENTS AVERAGED

METRIC dB(A)

OPERATION Level Flyover

SITE 150 m East

REFERENCE SLANT RANGE 500 Feet

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 83.1

SCALE : 1cm = 1dB outside reference semicircle

0 1 2 3 4

cm.

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS
-ANGLES INCREASE CLOCKWISE.

FLIGHT PATH

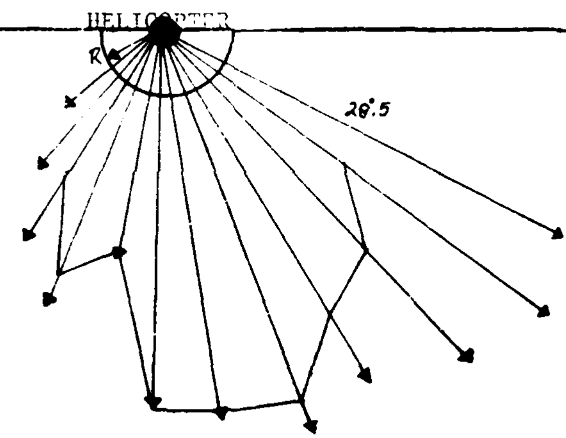


FIGURE 4.5.3

GROUND LEVEL

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER Gazelle SA 341

TEST DATE June 15, 1978

NUMBER OF EVENTS AVERAGED 5

METRIC dB(A)

OPERATION Takeoff

SITE 150 m East

REFERENCE SLANT RANGE 500 Feet

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 67.4

SCALE : 1cm = 1dB outside reference semicircle

0 1 2 3 4
cm

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

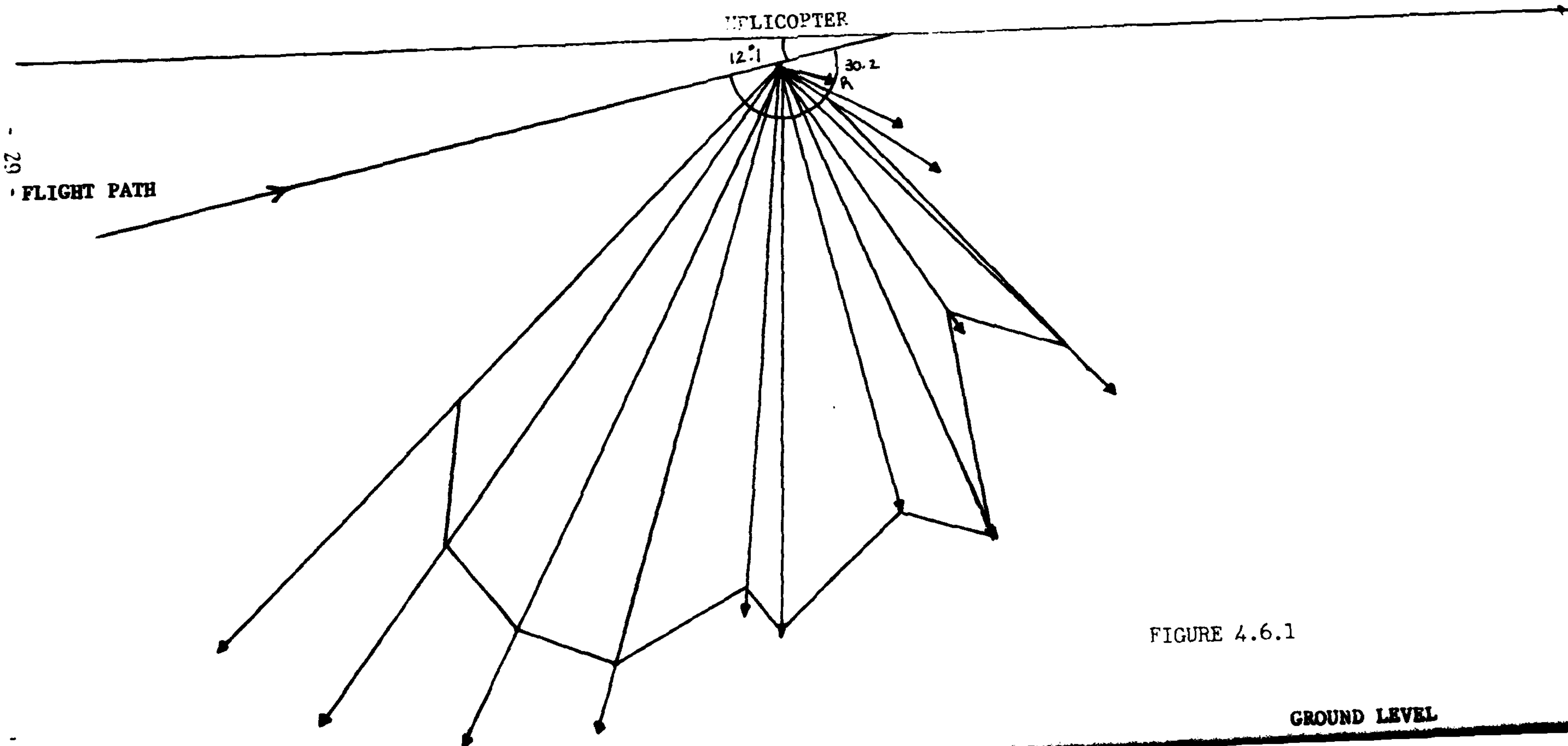


FIGURE 4.6.1

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER Gazelle SA-341

TEST DATE June 13, 1978

NUMBER OF EVENTS AVERAGED 6

METRIC dB(A)

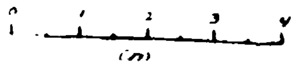
OPERATION APPROACH

SITE 150 m East

REFERENCE SLANT RANGE 500 feet

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 76.2

SCALE : 1cm = 1dB outside reference semicircle



NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

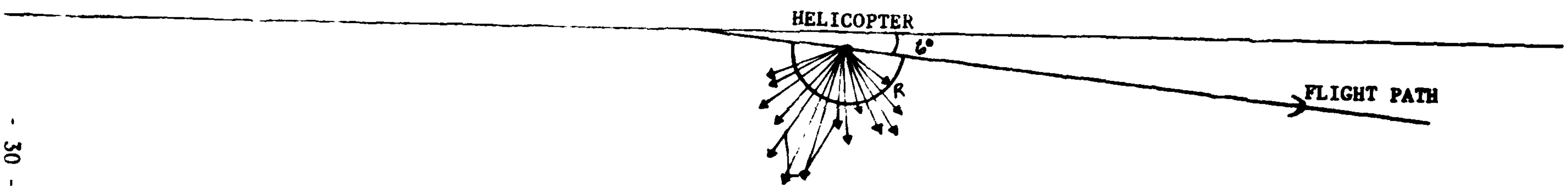


FIGURE 4.6.2

GROUND LEVEL

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER [illegible] | OPERATION Level Flyover
TEST DATE June 15, [illegible] | SITE 150 m East
NUMBER OF EVENTS AVERAGED [illegible] | REFERENCE SLANT RANGE 500 Feet
METRIC dB(A)
VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 75.8

SCALE : 1cm = 1dB outside reference semicircle

0 1 2 3 4
cm

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

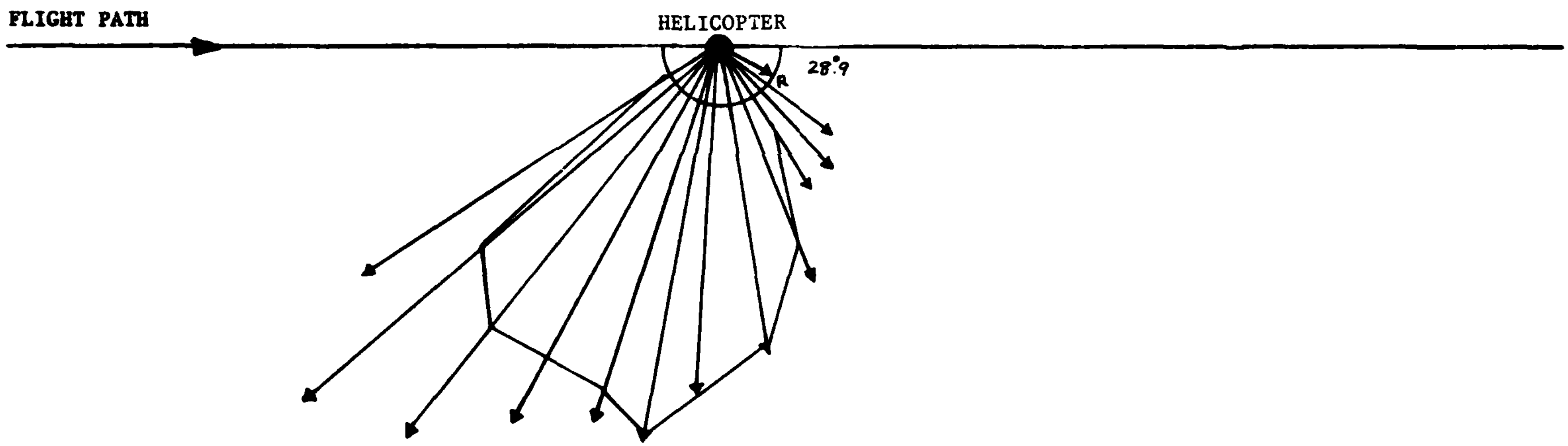


FIGURE 4.6.3

GROUND LEVEL

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER Bell 206L | OPERATION Takeoff

TEST DATE June 16, 1978 | SITE 150 m East

NUMBER OF EVENTS AVERAGED 6 | REFERENCE SLANT RANGE 500 Feet

METRIC dB(A)

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 72.3

SCALE : 1cm = 1dB outside reference semicircle

0 1 2 3 4
cm

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

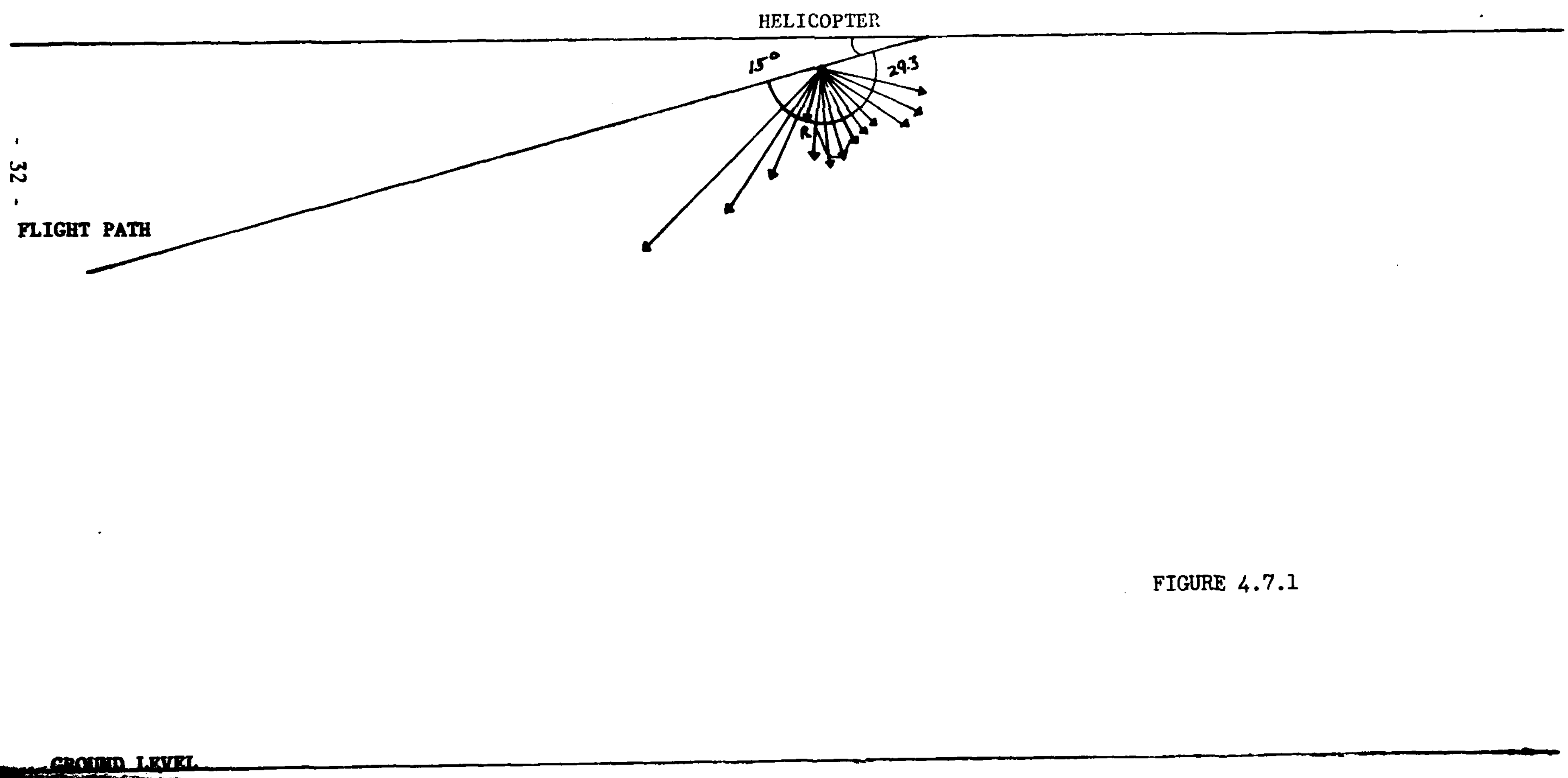


FIGURE 4.7.1

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER Bell 206L

TEST DATE June 16, 1978

NUMBER OF EVENTS AVERAGED 4

METRIC dB(A)

OPERATION APPROACH

SITE 150 m East

REFERENCE SLANT RANGE 500 Feet

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 72.2

SCALE : 1cm = 1dB outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

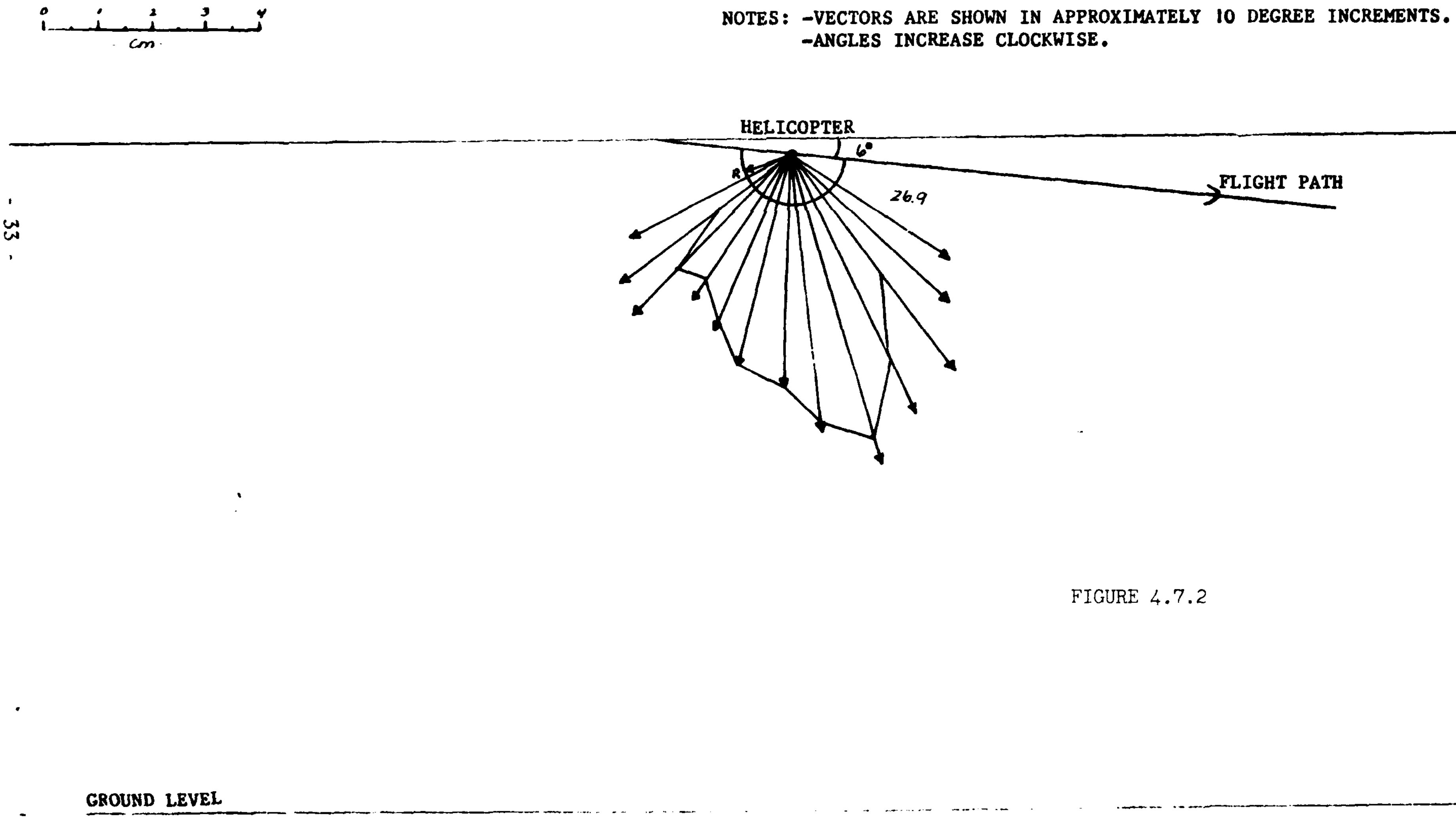


FIGURE 4.7.2

HELICOPTER D[illegible] ANALYSIS

HELICOPTER Bell 206L

TEST DATE June 16, [illegible]

NUMBER OF EVENTS AVERAGED 6

METRIC dB(A)

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 71.2

OPERATION Level Flyover

SITE 150 m East

REFERENCE SLANT RANGE 500 Feet

SCALE : 1cm = 1dB outside reference semicircle

0 1 2 3 4

cm

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENT
-ANGLES INCREASE CLOCKWISE.

FLIGHT PATH

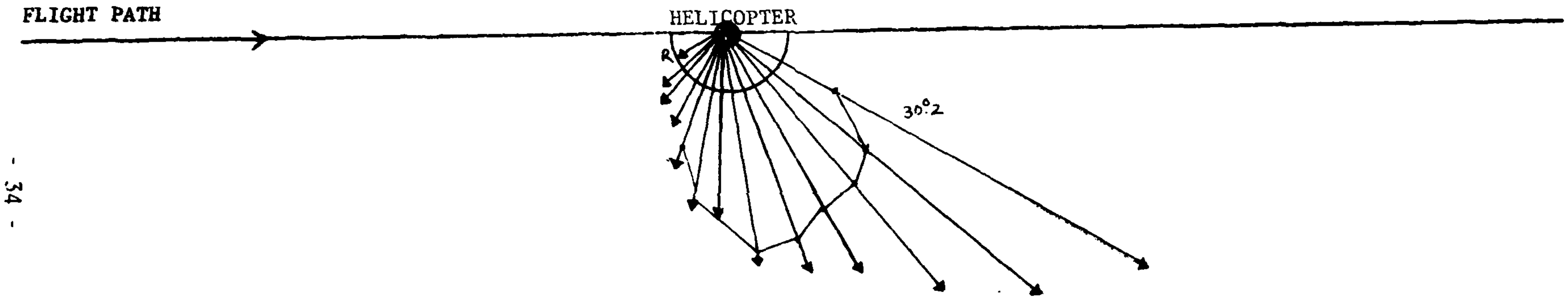


FIGURE 4.7.3

GROUND LEVEL

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER Hughes 500

TEST DATE June 16, 1978

NUMBER OF EVENTS AVERAGED 6

METRIC dB(A)

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 67.8

OPERATION Takeoff

SITE 150 m East

REFERENCE SLANT RANGE 500 Feet

SCALE : 1cm = 1dB outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

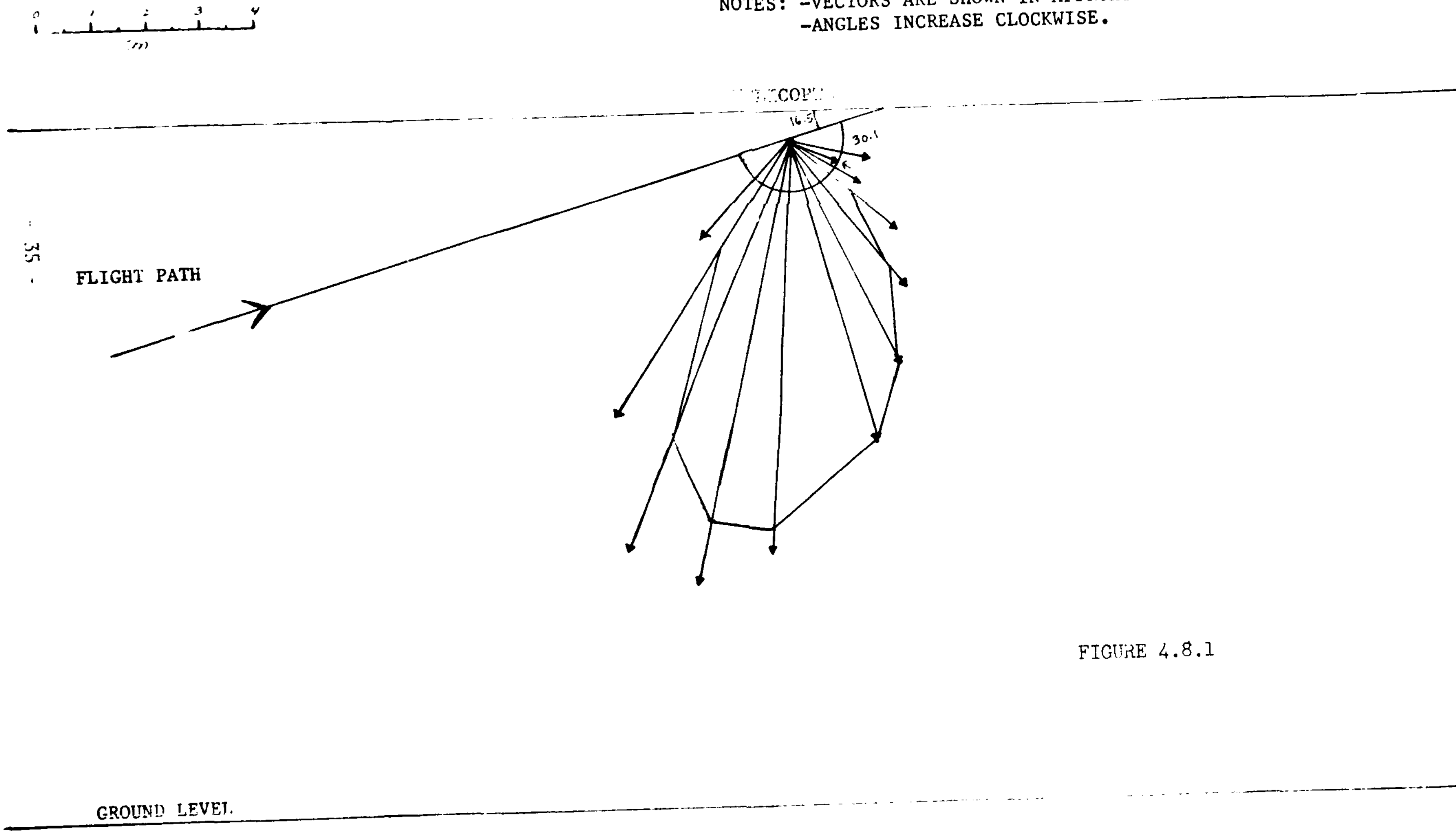


FIGURE 4.8.1

HELICOPTER ... ANALYSIS

HELICOPTER Hughes ... OPERATION APP...

TEST DATE ... SITE ...

NUMBER OF EVENTS AVERAGED ... REFERENCE SLANT RANGE ...

METRIC ...

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = ...

SCALE : 1cm = 1dB outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

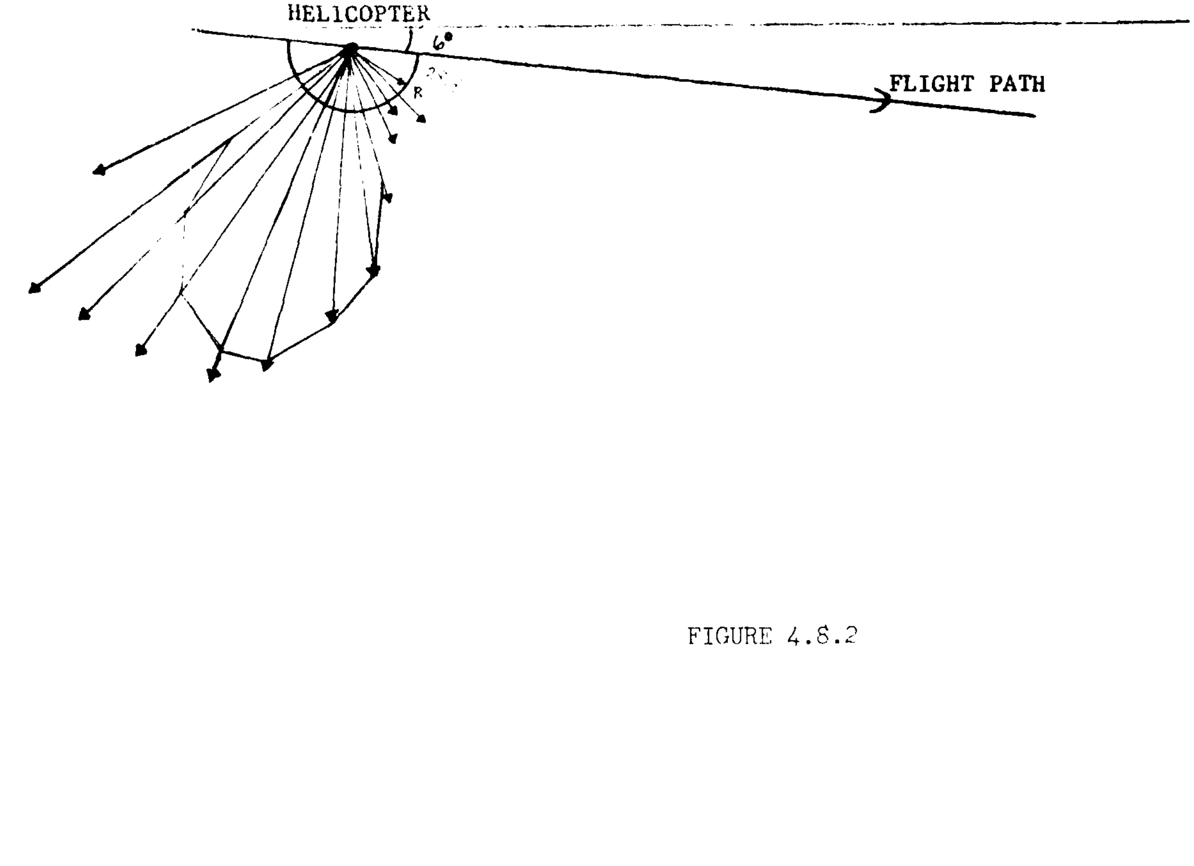


FIGURE 4.8.2

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER Hughes 500C

TEST DATE June 16, 1978

NUMBER OF EVENTS AVERAGED 6

METRIC dB(A)

OPERATION Level Flyover

SITE 150 m East

REFERENCE SLANT RANGE 500 Feet

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 73.4

SCALE : 1cm = 1dB outside reference semicircle

cm

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

FLIGHT PATH

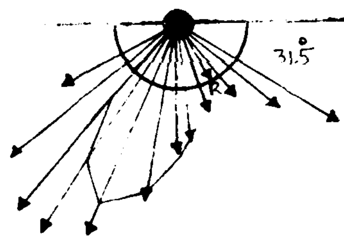


FIGURE 4.8.3

GROUND LEVEL

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4. Newman, J. S. and Rickley, S. J., "Noise Levels and Flight Profiles of Eight Helicopters Using Proposed International Certification Procedures," FAA-EE-79-03, March 1979.

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